

UK Nordic Baltic Hydrogen Conference

Hydrogen for road transport: public transport, HGV, private users – where to start?

2022

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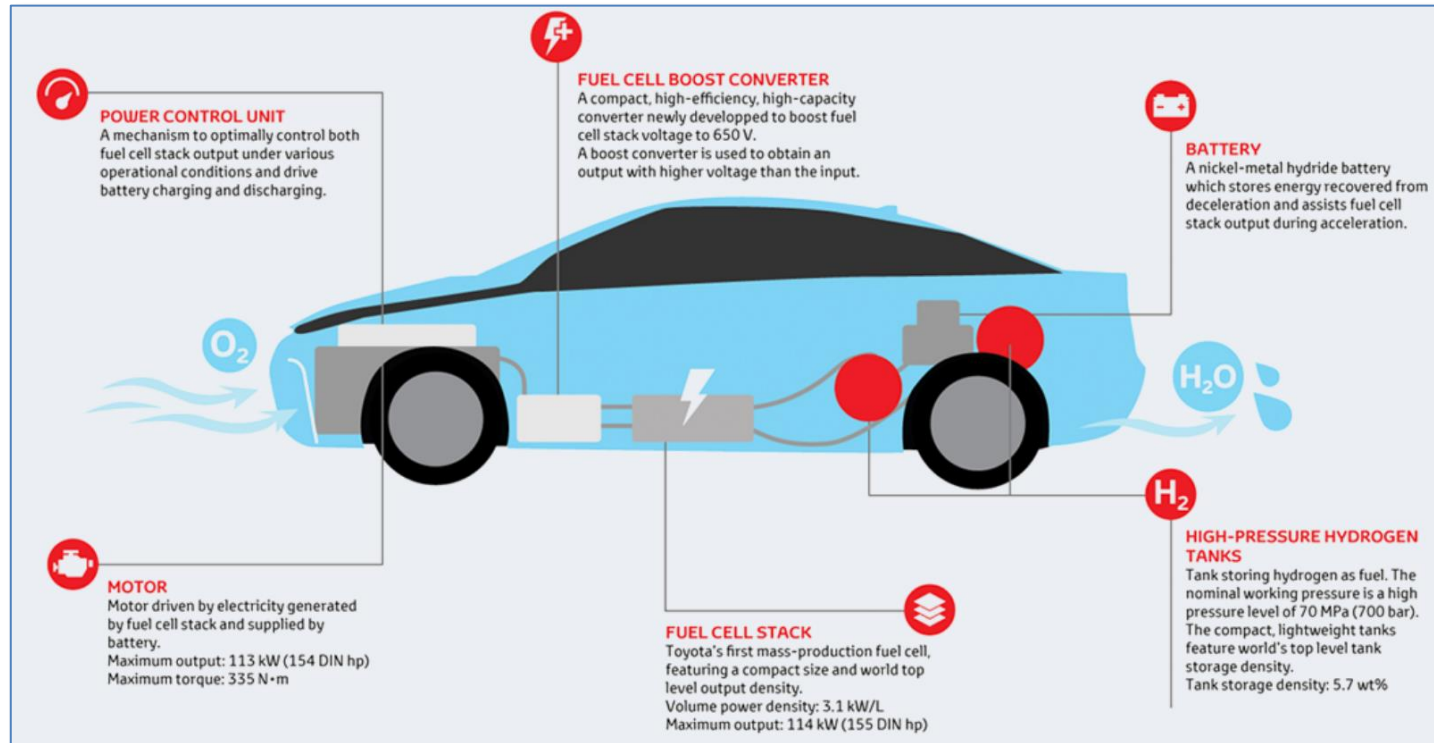
Agenda

Introduction to hydrogen fuel cells and the wider context

Where to start?

An introduction to hydrogen fuel cell technology for vehicles

Schematic representation of a fuel cell vehicle



- Hydrogen fuel cell vehicles are a type of electric vehicle but instead of a battery, a fuel cell vehicle contains a tank which can be filled with hydrogen gas.
- The hydrogen gas is drawn from the tank and enters the fuel cell where it combines with oxygen in the air to create an electric current which drives the vehicle. The only by product is water vapour

Hydrogen fuel cell technology has a high potential to decarbonise mobility

Hydrogen mobility's value proposition

1

Matches the duty cycles of fossil equivalents



Hydrogen vehicles have the **same range as fossil equivalents** and can refuel in ~3-15 minutes

2

Is an ultra low carbon technology



Hydrogen produced from renewable electrolysis or CCS has almost zero carbon footprint

3

Improves the local air quality



FCEVs emit only water vapour and have an air filter which reduces particulate pollution

4

Reduces fuel dependence and creates economic growth



Hydrogen can be produced locally so reduces reliance on oil exporting nations and fuel cell vehicle manufacturing can preserve high end European engineering jobs

5

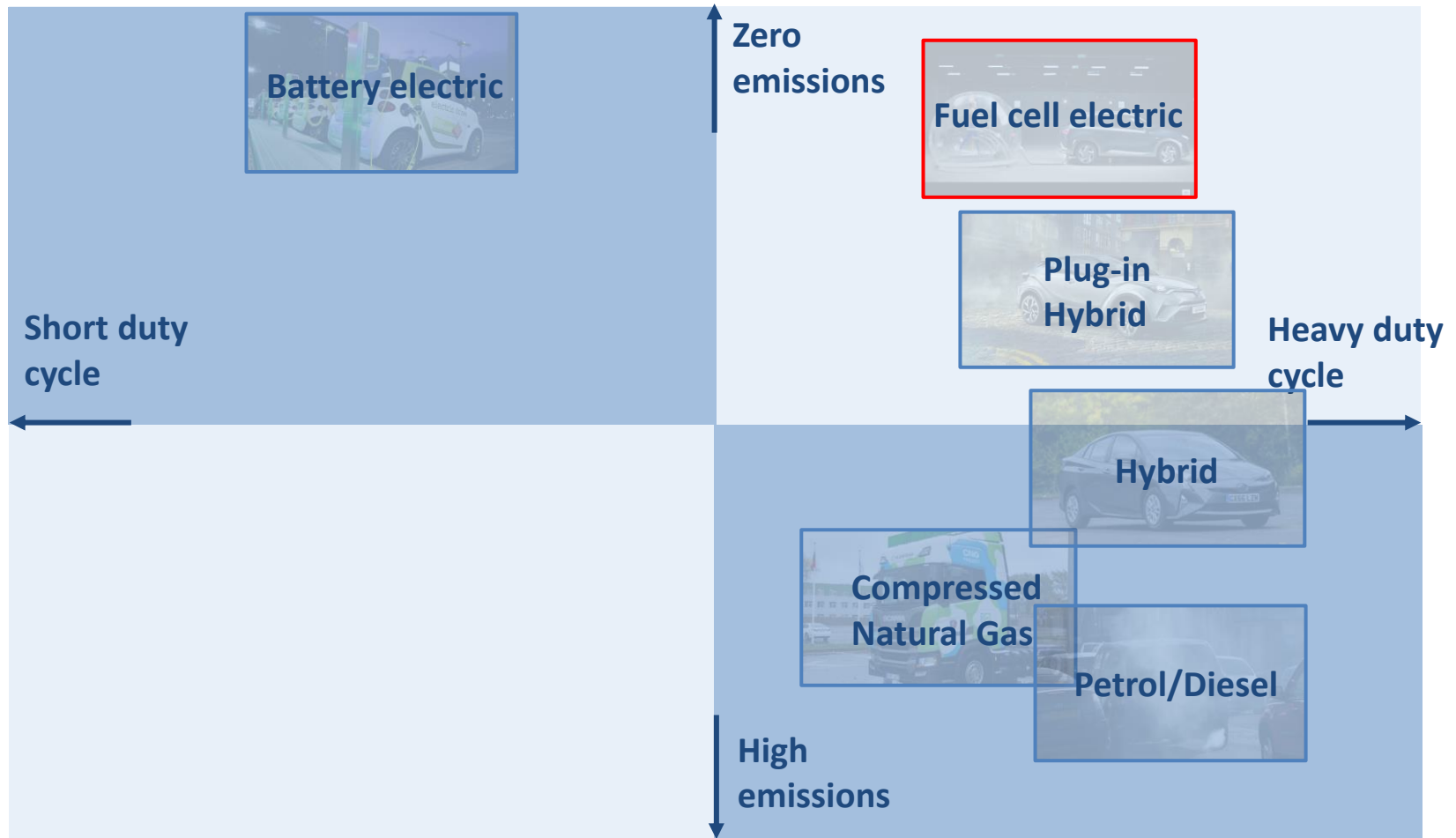
Can achieve parity with diesel in the future



Provided policy measures are introduced to meet decarbonisation goals and hydrogen costs come down with scale, we can expect hydrogen to achieve cost parity with diesel over the next ~10 years

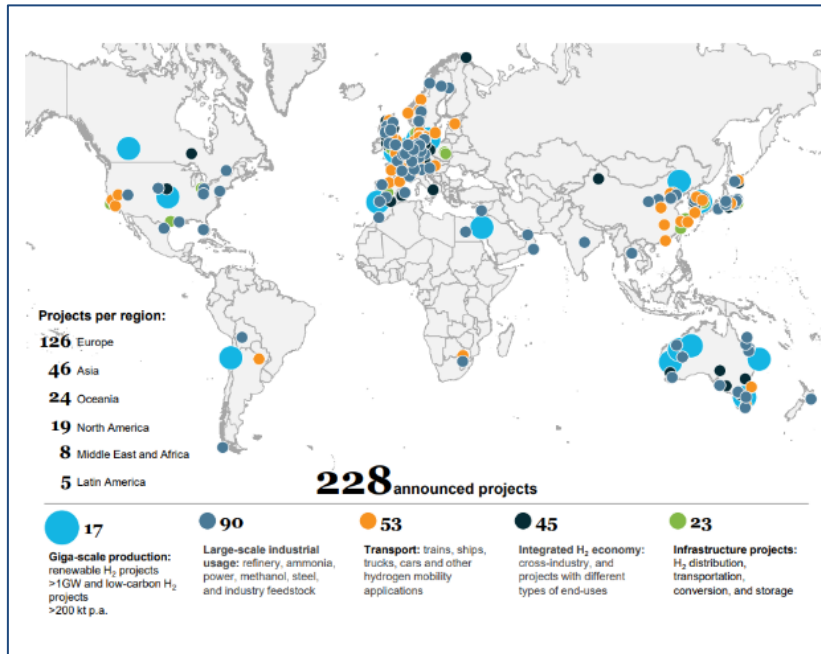
Fuel cell electric vehicles offer the same low emissions as battery electric while matching the duty cycles possible from conventional drivetrains

Graphic of emissions vs duty cycle for different powertrain types

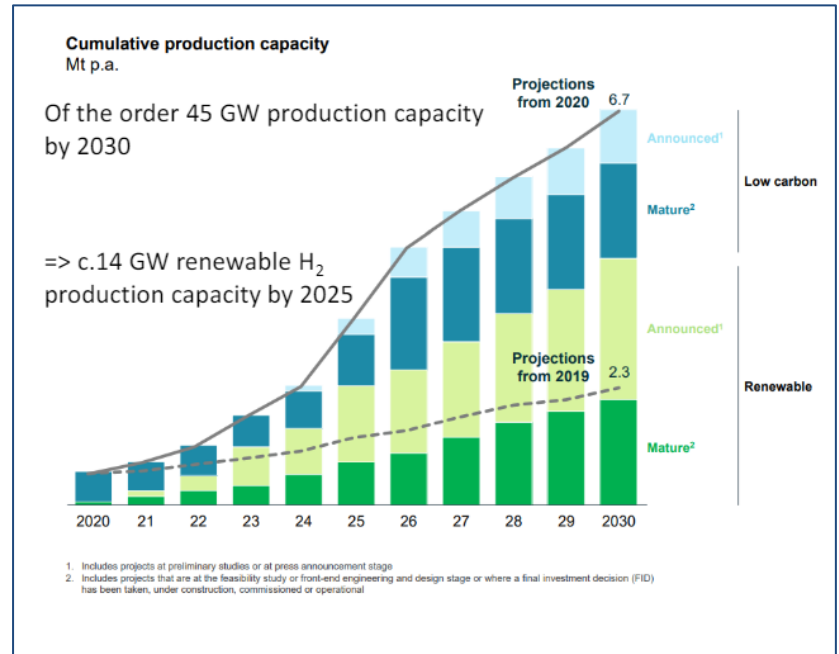


Interest in hydrogen production projects has grown rapidly in recent years and is expected to reach ~7 million tonnes per year by 2030

Total hydrogen projects announced globally



Planned hydrogen production capacity scale



- The Hydrogen Insights Report (2021) identified 228 hydrogen project around the world 17 of which are “giga-scale” i.e. >1GW of renewable capacity and >200ktH₂/yr

- Massive growth in hydrogen production capacity is expected out to 2030 – over 45 GW.
- Note the largest electrolyser currently used is 10MW at a Shell refinery.

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Progress and lessons

Strategic motorways networks and freight

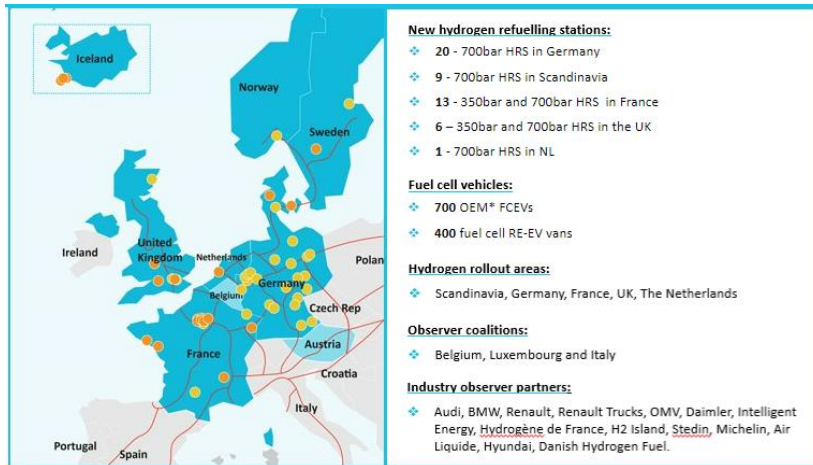
The multimodal city hub

The combined approach

It has already begun... there are ~1300 fuel cell vehicles in operation in Europe today

Car and Van deployments

- There are around 1080 passenger cars and vans as part of the H2ME vehicle programme across the majority of Western European countries.



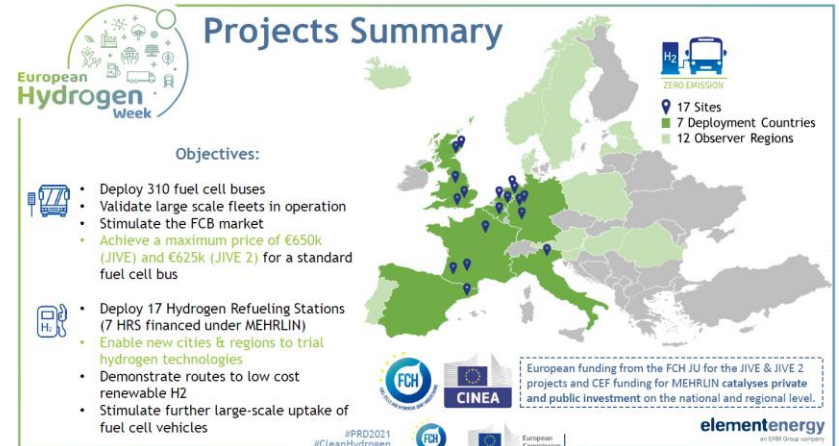
Truck deployments

- There are currently ~50 Hyundai fuel cell trucks operating in Switzerland and ~10 Hyzon fuel cell trucks in the Netherlands as well as many prototypes.

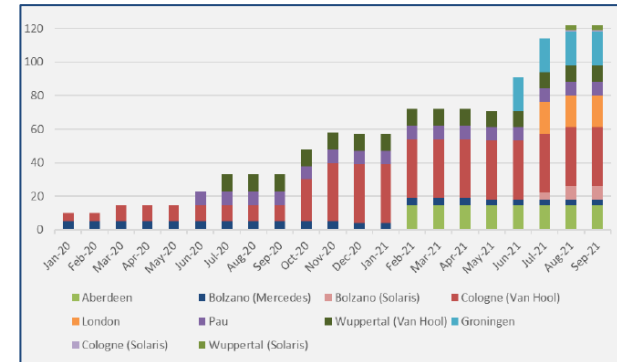


Bus deployments

- There are ~230 fuel cell buses with JIVE 1 & 2 programs having deployed over 100 buses in the past year and are on the path to more than 300.



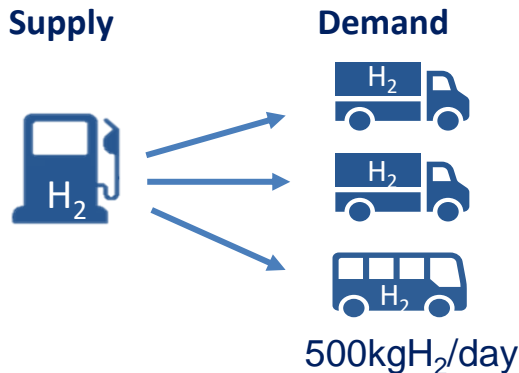
JIVE bus deployments



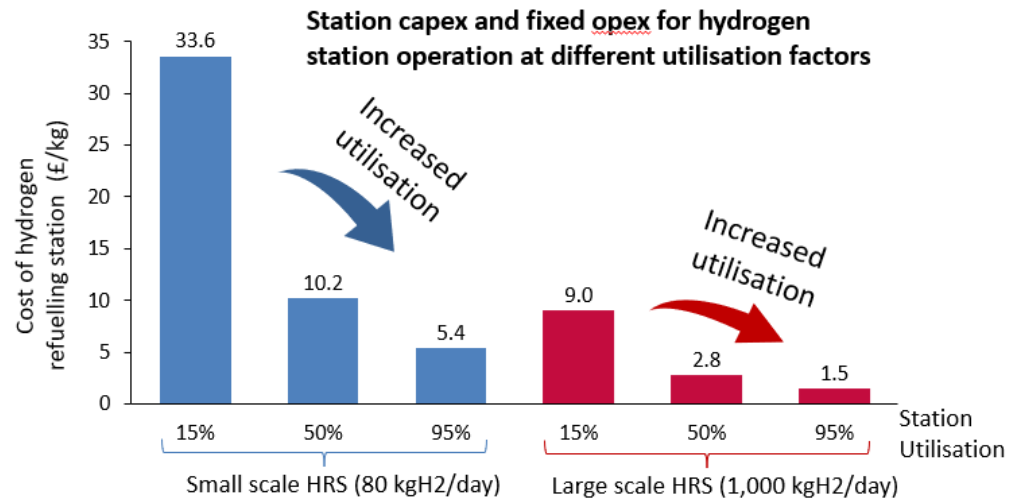
A key lesson is that jumping to scale in the hydrogen ecosystem is a rapid way to reduce vehicle ownership costs and improve performance

Rationale for aggregating demand

- **Scale reduces hydrogen fuel and vehicle costs**
 - Purchasing vehicles in larger quantities brings down capital costs.
 - The dispensed price of hydrogen drops rapidly with scale e.g. 1 HGV refuel per day would cost \$15/kg and 20 HGVs per day is >\$7/kg
- **Scale enables reliability**
 - It is possible to deploy ultra-reliable stations at scale due to the inbuilt redundancy of multiple dispenser units.
 - This is achieved by closely coupling station deployment with large vehicle demand.



HRS size and utilization with cost



The graphic illustrates that increased scale and utilisation of the hydrogen refuelling station (HRS) brings down the cost contribution of dispensing to the hydrogen price.

Scale can be achieved by aggregated demand across operators acting synchronously and collaboratively

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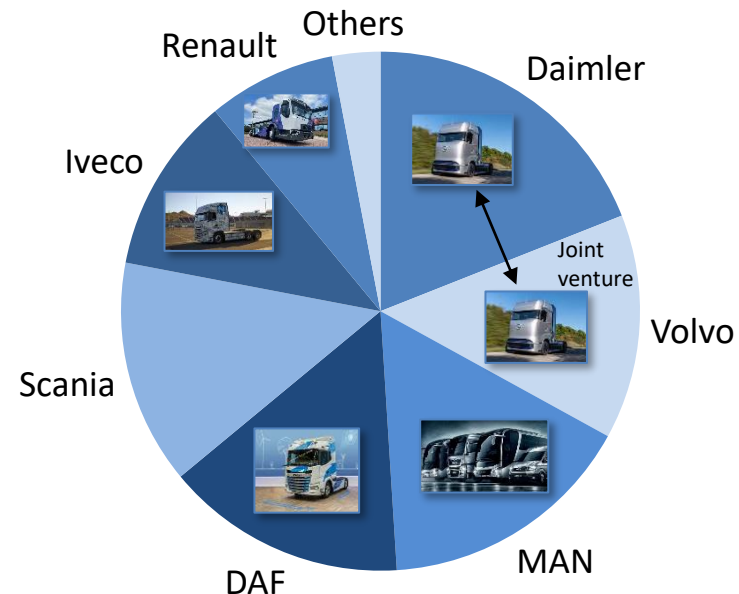
The combined approach

Global OEMs and new market entrants see hydrogen as a promising technology and are investing heavily into it

Plans for hydrogen vehicle deployments

- 6 of the 7 dominant European truck manufacturers have announced programs to develop fuel cell vehicles. Daimler and Volvo have announced a €1.2 billion joint product development program for fuel cell trucks.
- These 6 companies have plans for vehicles to enter series production between 2024-2028.
- This behaviour is being driven largely through EU CO2 emission standards for heavy-duty vehicles for reducing emissions from new trucks for 2025 (15%) and 2030 (30%). The 2030 target will require new non-fossil technologiesⁱⁱⁱ.
- New market entrants are moving faster, Hyundai are the EU market leaders with 50 hydrogen trucks operating in Switzerland with plans for 1600 by 2025. Hydrogen truck specialists Nikola and Hyzon also have 100s of trucks operating globally.

2020 EU truck market share & FC trucks



Hyundai trucks in Switzerland

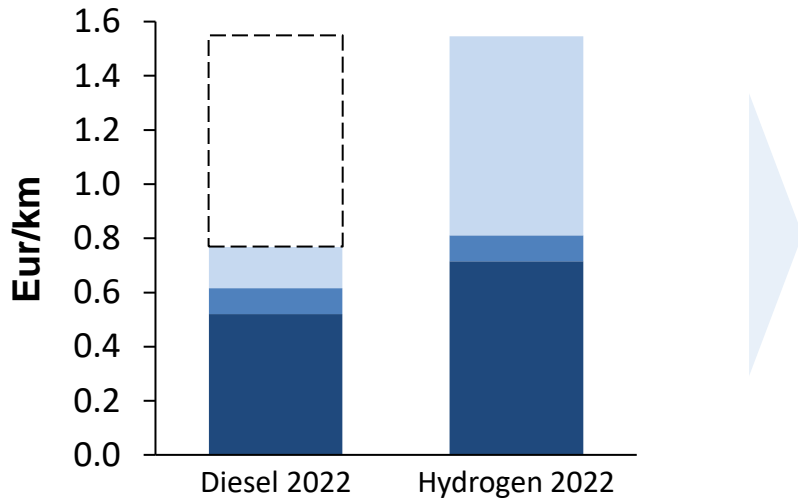


A Hyzon truck in the Netherlands



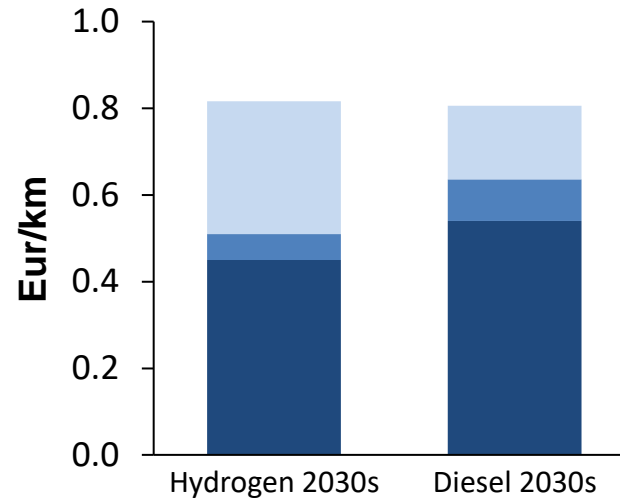
The major barrier to hydrogen vehicle deployment is the ownership cost

Hydrogen vs Diesel trucks presently



- At present, hydrogen fuel cell trucks are a nascent industry and a hydrogen truck is expected to cost around twice as much as diesel to own and operate.

Hydrogen vs Diesel trucks in future



- It is expected that diesel truck ownership costs will increase over the coming decade as fuel prices increase and emissions standards for new trucks drive up capital costs.

How do we overcome the ownership cost gap to get to the point of diesel price parity?

■ Fuel Cost ■ Maintenance Cost ■ Capital Cost □ Ownership cost gap

The Swiss 1600 trucks project has pioneered the concept of aggregated demand for hydrogen freight

Swiss 1600 truck overview organogram

Truck supplier



Fuel suppliers



Truck operators



- The project now has 46 trucks in operation across 9 stations and aims for 1600 trucks by 2025.
- The combination of aggregated demand and generous road tax exemptions for zero emission vehicles (~€50,000/year) allowed the project to pioneer.

Swiss Truck Refuelling Stations



First trucks operated by the 7 original operators



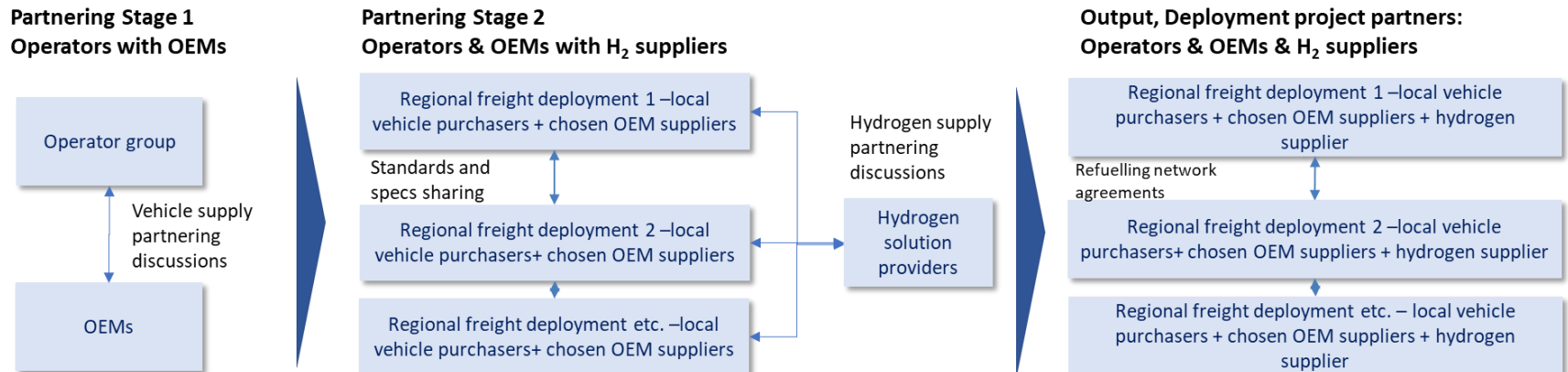
Government support schemes for zero emission trucks are being announced across Europe

Government support schemes are being announced in Europe and Globally

- Germany has already announced a scheme to subsidise 80% of vehicle and infrastructure delta costs to diesel vehicles with any company able to claim up to €15 million per year. States surrounding Germany are expected to announce similar schemes.
- The UK is expected imminently to announce a c.£100 million fund called the Zero Emission Road Freight Trail.
- France has introduced tax break laws which allow a 40% over depreciation of low carbon trucks.

The aggregated demand partnering process

- The approach is to target early, competitive partnering between OEMs and operators and then once deployment clusters are established, to partner with infrastructure providers for hydrogen freight deployment projects.



Numerous projects are looking to copy this approach across Europe and even round the world

H2Accelerate

- H2Accelerate is a collaboration with the aim to accelerate the use of hydrogen as a fuel for heavy duty road transport in Europe.
- The group targets 60,000 trucks and 400 stations in operation across Europe by 2030.



AHFC Aggregated Hydrogen Freight Consortium

- The UK Aggregated Hydrogen Freight Consortium aims to accelerate the deployment of fuel cell vehicles for freight applications
- The group expects to deploy 100 fuel cell trucks in the UK by 2025 and 1000s by 2030.



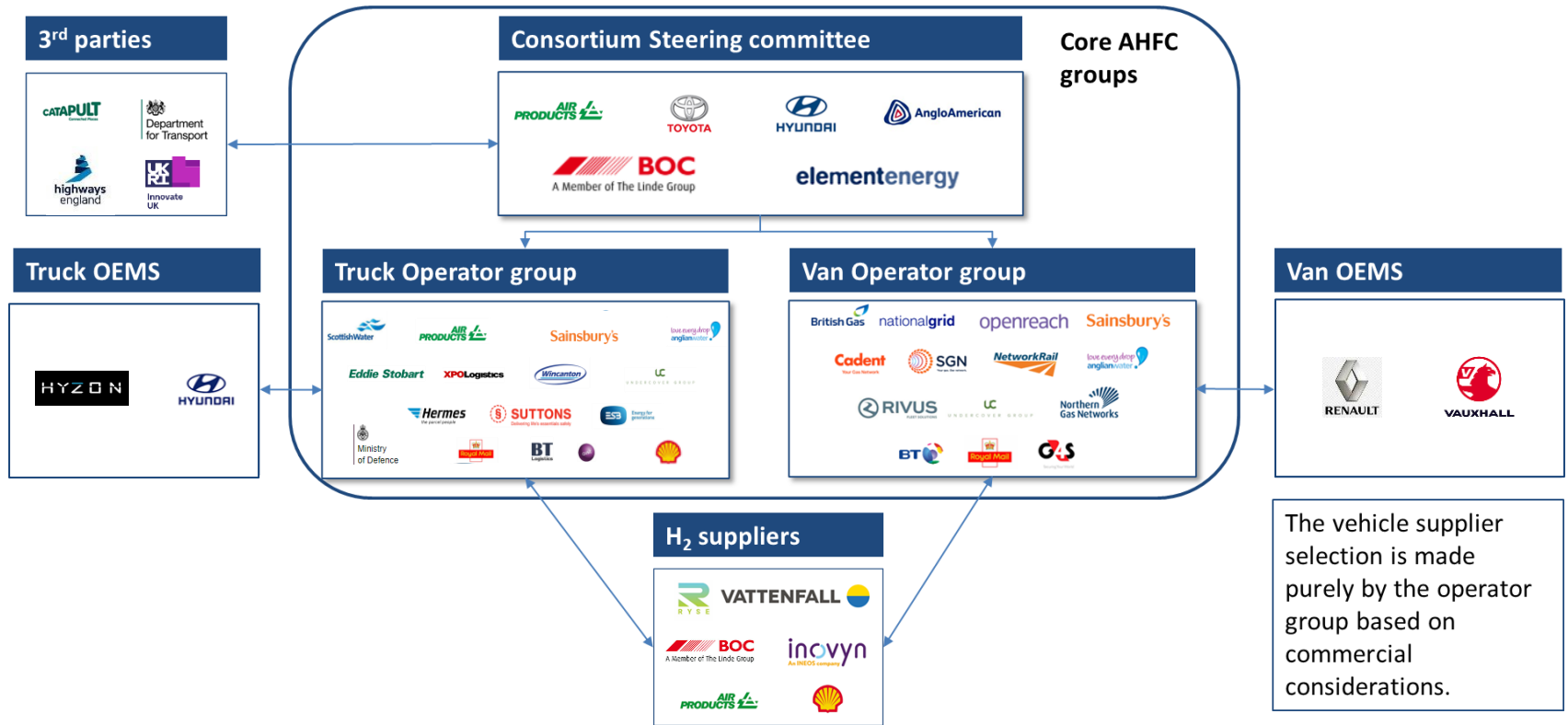
HyTrucks

- HyTrucks one of Europe's largest initiatives aiming to deploy zero-emission heavy vehicle fleets in the region aims to have 1000 hydrogen-powered trucks in Belgium, The Netherlands and West Germany by 2025



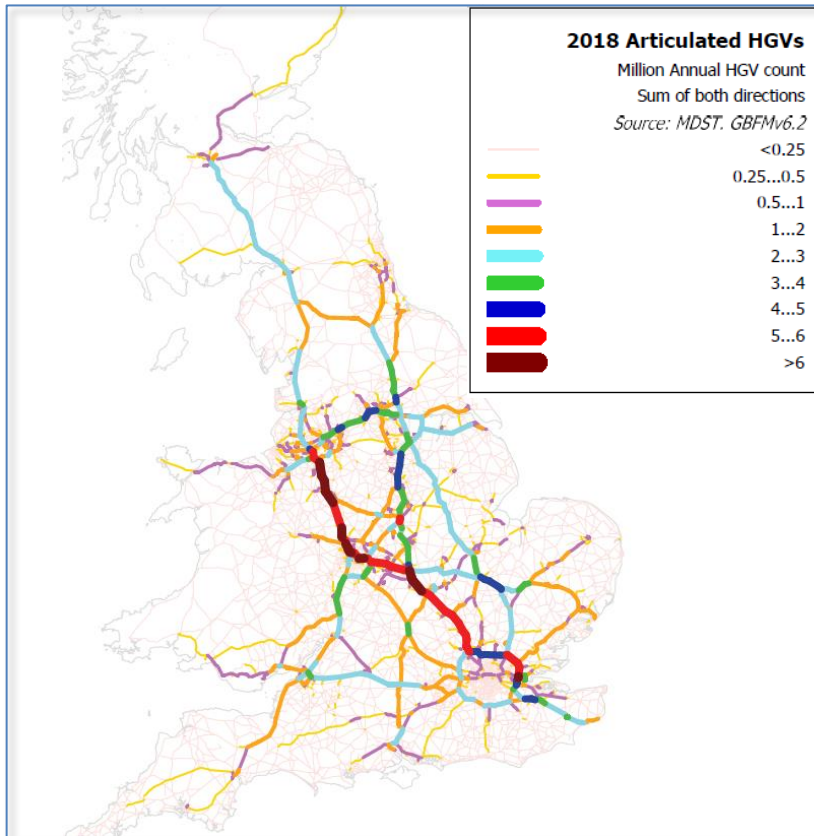
The Aggregated Hydrogen Freight Consortium is a demand led project to accelerate the deployment of fuel cell trucks and vans in the UK

Overview of the AHFC members

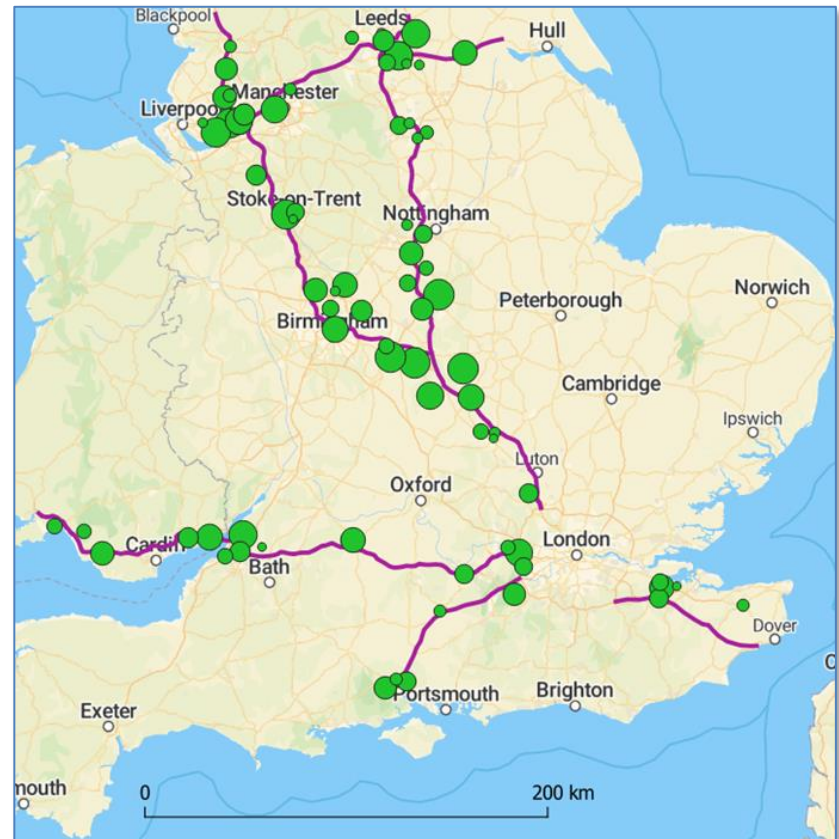


The group is also looking to develop intercity hydrogen hubs on major truck routes in the UK

Major routes which artic trucks operate on



AHFC depots near major motorways



- Truck route data and depot locations point strongly to refuelling stations being deployed close to clusters of truck depots along the London, Liverpool and Leeds “Y-shape” trunk routes.

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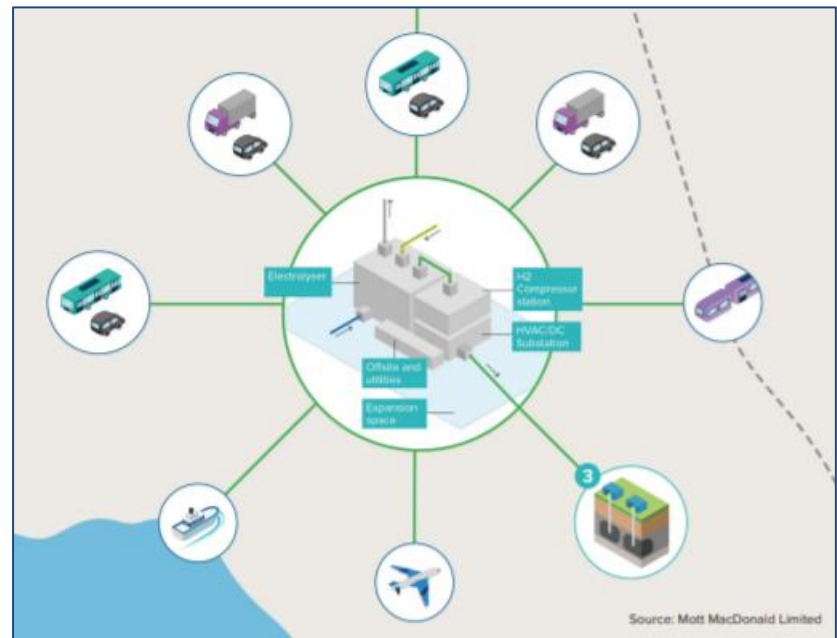
The combined approach

The multimodal hydrogen vehicle valley/hub concept looks to achieve scale around transport hubs

Multimodal hydrogen hub concept

- The second deployment strategy which is being pioneered successfully is the hydrogen transport hub concept.
- This aims to achieve scale of refuelling system by coordinating a large number of multimodal hydrogen vehicle operators to purchase vehicles synchronously and collaboratively.
- The process of starting finds a transport hub e.g. city, airport, port etc. and seeks to build a minimum of two/three large, public hydrogen stations which have anchor tenants

Hub visualisation



The range of hydrogen vehicles available to cities has expanded rapidly over the past 2-3 years

Hydrogen vehicle classes



Light weight municipal / Private hire vehicles

H2 demand: 2kg/day

- Fully developed market and available to order in the 100s in the UK



Forklifts

H2 demand: 1kg/day

- Toyota will be demonstrating the first UK FC forklift at the Teesside International airport from January 2022



Vans

H2 demand: 2kg/day

- Renault/ Vauxhall vans will be available from 2022/2024.



Delivery Trucks

H2 demand: 15kg/day

- Hyundai lead with UK start-up Electra doing first demonstration trials in 2021, large OEM models expected in ~2023



Refuse collection vehicles

H2 demand: 20kg/day

- Only diesel combustion engine retrofits are currently available. Fuel cell models are expected in ~2024



Trains

H2 demand: 300kg/day

- Alstom are in negotiations with parties to deploy the first H2 trains in the UK in 2023



Buses

H2 demand: 15kg/day

- 20 buses in operation. Two UK based OEMs building production lines capable of meeting orders for 100s of FC buses



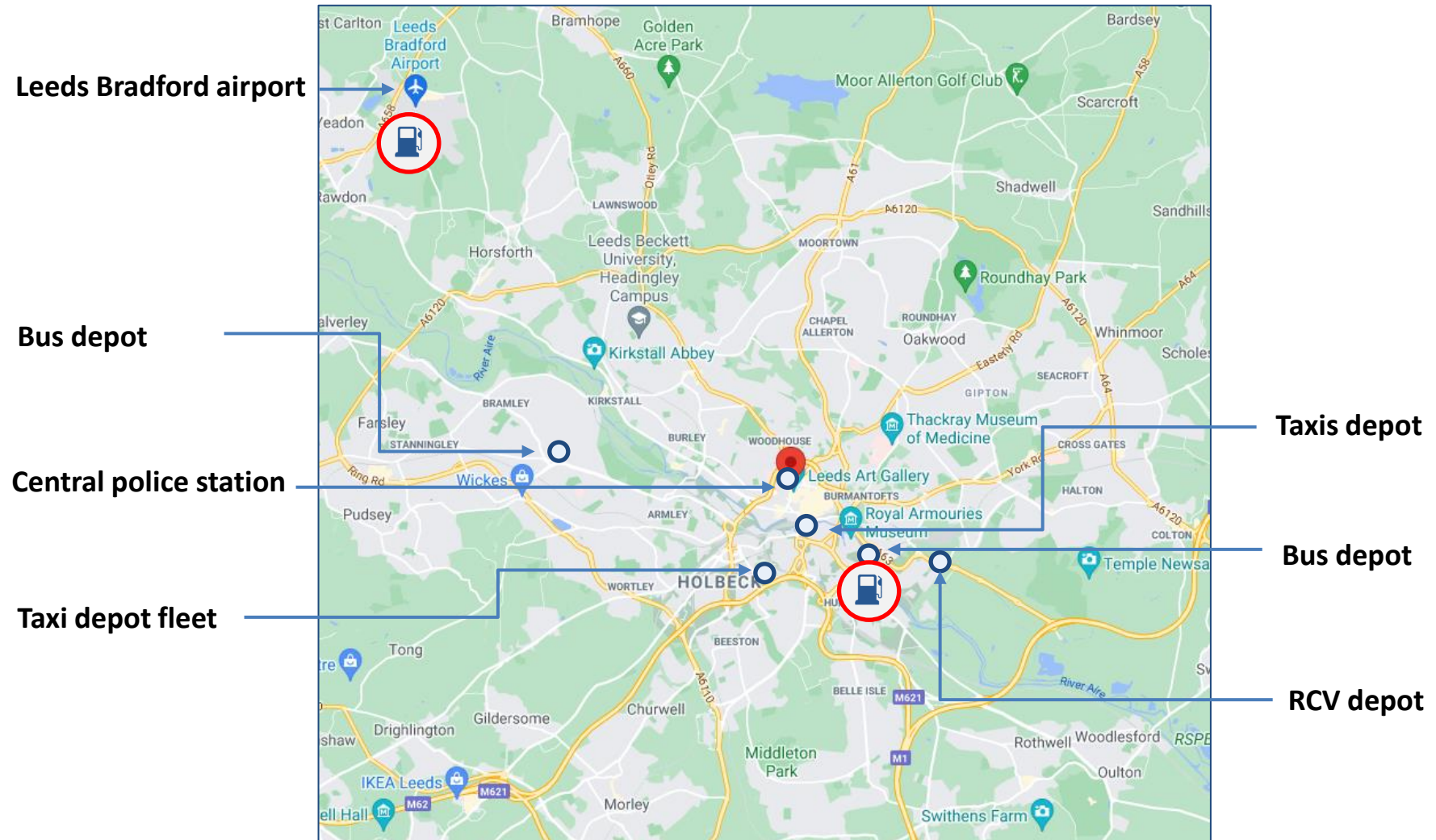
Ships

H2 demand: 500kg/day

- Government's clean maritime competition will open in the spring of 2022.

The hub concept can be applied to any city with sufficiently large transport demand

Indicative overview map of a Transport Hub Concept in Leeds UK



Hydrogen valley and transport hub concepts are being delivered across Europe and in the UK

Example projects

The French "Zero Emission Valley" obtains a European financial support



UK invests £3 million in Tees Valley hydrogen transport hub

By Dominic Ellis
March 17, 2021 • 3 mins

Jan 26, 2021 - 09:48 pm

HysetCo moves to run 600 hydrogen cabs in Paris

AIR LIQUIDE FCEV FRANCE HYPE HYSETCO PARIS SLOTA STEP TOYOTA



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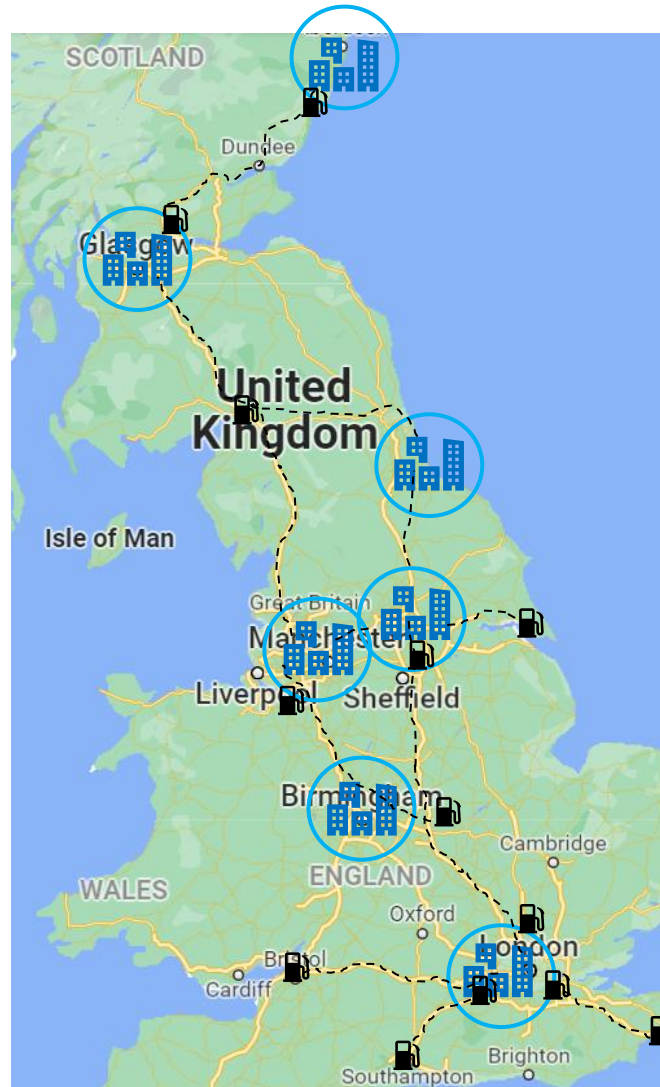
The combined approach

By joining the trunk route strategy with a city scale hub strategy, a nation can create a cost effective, nationwide refuelling network

Indicative strategy for how the UK might create an H2 strategy

Description of approach

- Marry the hydrogen hub concept with the truck trunk route strategy in a hub and spoke model and create a network of large, well loaded public stations that allow any vehicle to travel relatively freely across large distances.
- This will need centrally coordinated and efficiently spent public funds of the total magnitude of ~£200-300M and could be achieved by any country.
- This represents a relatively low cost way to begin decarbonising the hard to treat transport sectors



Key



City based hydrogen transport hub



Strategic motorway network unlocked for freight



Motorway based refuelling stations

Thanks for listening